UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS AND ENGINEERING MATHEMATICS

MODULE PHY1DB1

CAMPUS DFC

EXAM NOVEMBER 2014

DATE: 14/11/2014 **SESSION** 08:30 – 11:30

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DURATION: 3 HOURS **MARKS:** 150

NUMBER OF PAGES: 19 PAGES

INSTRUCTIONS

Answer all the questions.

Calculators are permitted.

Answer SECTION A on UJ multiple choice answer sheet provided.

Answer SECTION B in the answer book provided.

SECTION A

1. Which best describes the relationship between two systems in thermal equilibrium?

   A. no net energy is exchanged
   B. volumes are equal
   C. masses are equal
   D. zero velocity

2. Metal lids on glass jars can often be loosened by running them under hot water. Why is this?

   A. The hot water is a lubricant.
   B. The metal and glass expand due to the heating, and the glass being of smaller radius expands less than the metal.
   C. The metal has a higher coefficient of thermal expansion than glass so the metal expands more than the glass thus loosening the connection.
   D. This is just folklore.

3. A rectangular steel plate with dimensions of 30 cm $\times$ 25 cm is heated from 20°C to 220°C. What is its change in area? (Coefficient of linear expansion for steel is 11×10^{-6}/C°.)

   A. 0.82 cm^2
   B. 1.65 cm^2
   C. 3.3 cm^2
   D. 6.6 cm^2

4. As a copper wire is heated, its length increases by 0.100%. What is the change of the temperature of the wire? ($\alpha_{Cu} = 16.6 \times 10^{-6}$/C°)

   A. 120.4°C
   B. 60.2°C
   C. 30.1°C
   D. 6.0°C

5. A 2.00 L container holds half a mole of an ideal gas at a pressure of 12.5 atm. What is the gas temperature? (R = 0.0821 L·atm/mol·K)

   A. 1980 K
   B. 1190 K
   C. 965 K
   D. 609 K

6. Two moles of nitrogen gas are contained in an enclosed cylinder with a movable piston. If the gas temperature is 298 K, and the pressure is 1.01 $\times$ 10^6 Pa, what is the volume? (R = 8.31 J/mol·K)

A. $9.80 \times 10^{-3}\ m^3$
B. $4.90 \times 10^{-3}\ m^3$
C. $17.3 \times 10^{-3}\ m^3$
D. $8.31 \times 10^{-3}\ m^3$

7. Two moles of an ideal gas at 3.0 atm and 10°C are heated up to 150 °C. If the volume is held constant during this heating, what is the final pressure?

A. 4.5 atm
B. 1.8 atm
C. 0.14 atm
D. 1.0 atm

8. 1.0 kg of water at 100 ºC is mixed with 2.0 kg of water at 20 ºC. What is the final temperature of the mixture? The specific heat capacity of water is 4200 J/kg ºC.

A. $27\ ^0C$
B. $37\ ^0C$
C. $47\ ^0C$
D. $57\ ^0C$

9. 0.100 kg of an unknown metal at 94 ºC is placed in 100 grams of water at 10 ºC. The final temperature of the metal and water are 17 ºC. What is the heat capacity of the unknown metal? The specific heat capacity of water is 4200 J/kg ºC.

A. 2.8×10^2 J/kg ºC
B. 3.8×10^2 J/kg ºC
C. 4.8×10^2 J/kg ºC
D. 5.8×10^2 J/kg ºC

10. A piece of copper at 90 ºC is added to 0.200 kg of water at 15 ºC inside an aluminium calorimeter that has a mass of 0.100 kg. The final temperature of the copper, water, and calorimeter is 25 ºC. What is the mass of the copper piece? The specific heat capacities of copper, water and aluminium are 385 J/kg ºC, 4200 J/kg ºC and 910 J/kg ºC, respectively.

A. 0.37 kg
B. 0.47 kg
C. 0.57kg
D. 0.67 kg

11. A 0.100 kg piece of metal is heated to 480 ºC and then quickly placed in 0.250 kg of water at 20 ºC which is contained in a 0.200 kg aluminium calorimeter. The final temperature of the water, metal and calorimeter is 36 ºC. What is the specific heat capacity of the metal piece? The specific heat capacities of water and aluminium are 4200 J/kg ºC and 910 J/kg ºC, respectively.

A. 2.2×10^2 J/kg ºC
B. 3.3×10^2 J/kg ºC
C. 4.4×10^2 J/kg ºC
D. 5.5×10^2 J/kg ºC

12. Barbara pours some 95°C water into a cup of instant noodles. The final temperature of the mixture is 85°C. If the masses of the hot water and noodles are 500 g and 150 g, respectively, calculate the specific heat capacity of the noodles. The original temperature of the noodles is 25°C and the specific heat capacity of water is 4 200 J kg^{-1} $°C^{-1}$.

A. 500.2 J kg^{-1} $°C^{-1}$
B. 1 076.9 J kg^{-1} $°C^{-1}$
C. 2 333.3 J kg^{-1} $°C^{-1}$
D. 8 000.4 J kg^{-1} $°C^{-1}$

13. A 13 kg piece of zinc at 70 ^{0}C is placed in a container of water. The water had a mass of 25 kg and a temperature of 22 ^{0}C before the zinc was added. What is final temperature of water and zinc? The specific heat of zinc is 388 J kg^{-1} $°C^{-1}$and of water is 4180 J kg^{-1} $°C^{-1}$.

A. 24.21 ^{0}C
B. 34.21 ^{0}C
C. 44.21 ^{0}C
D. 54.21 ^{0}C

14. You have 180 g of water in a 51 g calorimeter cup at a temperature of 25 ^{0}C. You drop 500 g piece of metal at a temperature of 130 ^{0}C into the calorimeter cup and the temperature stabilizes at 55 ^{0}C. How much heat did the calorimeter cup absorb? The specific heat of water is 1 cal g^{-1} $^oC^{-1}$ and that of the calorimeter is 0.21 cal g^{-1} $^oC^{-1}$.

A. 121.3 cal
B. 221.3 cal
C. 321.3 cal
D. 431.3 cal

15. A student drops two metallic objects into 291 g steel container holding 294 g of water at 30 ^{0}C. One object is a 173 g cube of copper that is initially at 51 ^{0}C and the other is a chunk of aluminium that is initially at 7 ^{0}C. To the student's surprise, the water reaches a final temperature of 30 ^{0}C, precisely where it started. What is the mass of the aluminium chunk? Assume that the specific heat of copper and aluminium are 387 J kg^{-1} $°C^{-1}$ and 899 J kg^{-1} $°C^{-1}$, respectively.

A. 38 g
B. 48 g
C. 58 g
D. 68 g

16. As I use sandpaper on some rusty metal, the sandpaper gets hot because:

A. heat is flowing from the sandpaper into the metal.
B. heat is flowing from the metal into the sandpaper.
C. frictional processes increase the internal energy of the sandpaper.
D. heat is flowing from my hand into the sandpaper.

17. John heats a 1 kg of soup (c = 4187 J kg^{-1} $°C^{-1}$) from 25°C to 70°C for 15 minutes by a heater. How long does the same heater take to heat 1.5 kg of the same kind of soup from 20°C to 80°C? The energy output per unit time by the heater is constant.

A. 25 minutes
B. 45 minutes
C. 30 minutes
D. 60 minutes

18. The temperature of steam at around 540 ^{0}C can be measured by

A. thermometer
B. radiative pyrometer
C. thermistor
D. thermocouple
E. thermopile

19. Heat flows from one body to the other when they have

A. different heat contents
B. different specific heat
C. different atomic structure
D. different temperatures

20. The amount of heat flow through a body by conduction is

A. directly proportional to the surface area of the body
B. directly proportional to the temperature difference on the two surfaces of the body
C. dependent upon the material of the body
D. inversely proportional to the thickness of the body
E. all of the above

21. During a physics lab, Ray Zuvlight observes a laser line passing through an unknown material towards a boundary with air with an angle of incidence of 24.5°. The light ray emerges into the air with an angle of refraction of 33.8°. Determine the index of refraction of the unknown material.

A. 1.24
B. 1.34
C. 1.44
D. 1.54

22. A wavelength of 633 nm is numerically equivalent to

A. 0.633 µm and 633 x 10^{-9} m
B. 0.633 mm and 63.3 x 10^{-8} m
C. 0.0633 m and 633 x 10^{-4} m
D. 6.33 mm and 63.3 x 10^{-5} m

23. Using the speed of light in vacuum, calculate how long it takes a light signal to travel on a straight line from Denver to New York, a distance of 2 000 km.

A. 6.67×10^{-3} s
B. 0.67 s
C. 6.67×10^{-6} s
D. 3.3×10^{-3} s
E. 13.2×10^{-3} s

24. Radio Station KGNU broadcasts at a frequency of 88.5 MHz. The wavelength of this signal is about

A. 3.4 m
B. 3.4 km
C. 34 m
D. 1.8 m
E. 1.8 km

25. Which of the following statements is ***true***?

A. The magnification of a pinhole camera increases when the screen used to display the image is moved further away from the pinhole (leaving everything else the same)
B. The magnification of a pinhole camera increases when the object is moved further away from the pinhole (leaving everything else the same)
C. The image produced by a pinhole camera is always the same size as the object, but is inverted
D. The magnification of a pinhole camera depends on the wavelength of the light that is used to illuminate the object
E. The magnification of a pinhole camera depends on the size of the pinhole

26. If the index of refraction of a medium is 1.25, the speed of light in that medium is

A. 240 000 km/s
B. 260 000 km/s
C. 220 000 km/s
D. 240 000 m/s

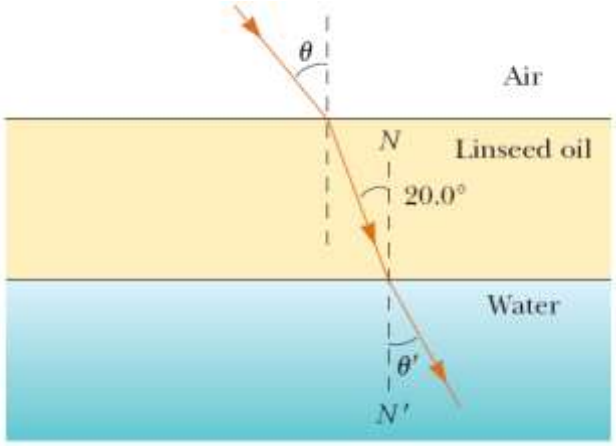
27. A laser beam is incident at an angle of 30.0° to the vertical onto a solution of corn syrup in water. The beam is refracted to 19.24° to the vertical. Suppose the light is red with wavelength 632.8 nm in a vacuum. Determine its wavelength in the solution.

A. 417 nm
B. 517 nm
C. 617 nm
D. 717 nm

28. In an effort to read the miniaturized writing in Khaled's lab notebook, Mr. H pulls a magnifying glass from his drawer. He places the magnifying glass a distance of 6.3 cm from the paper and produces an upright image of the writing which is magnified by a factor of 4.8. Determine the focal length of the lens used by the magnifying glass.

A. 5.0 cm
B. 6.0 cm
C. 7.0 cm
D. 8.0 cm

29. The light beam shown below makes an angle of 20.0° with the normal line *NN*' in the linseed oil. Determine the angles θ and θ'. The refractive indices for linseed oil and water are 1.48 and 1.33, respectively.



A. $\theta = 20.4^0$ and $\theta' = 22.3^0$

B. $\theta = 30.4^0$ and $\theta' = 22.3^0$
C. $\theta = 40.4^0$ and $\theta' = 22.3^0$
D. $\theta = 40.4^0$ and $\theta' = 32.3^0$

30. The focal point of a lens is located 17.8 cm away from its surface. The lens produces a virtual image which is 38.9 cm from the lens. Determine the object distance.

A. 12.2 cm
B. 14.2 cm
C. 16.2 cm
D. 18.2 cm

31. A lens produces a virtual image located 33.8 cm from the lens when the object is located 18.5 cm from the lens. Determine the focal length of the lens. What kind of lens is it?

A. f = 40.9 cm and lens type: converging
B. f = 40.9 cm and lens type: diverging
C. f = 50.9 cm and lens type: converging
D. f = 50.9 cm and lens type: diverging

32. In a converging lens lab, Anna Litical is challenged to determine the object distance which produces a real image which is magnified by a factor of five. The lens has a focal length of 12.0 cm. What object distance would you expect to produce this magnification?

A. 12.4 cm

B. 14.4 cm

C. 16.4 cm

D. 18.4 cm

33. An upright image is reduced to one-fourth of the object's height when the object is placed 26.9 cm from the lens. Determine the focal length of the lens.

A. -8.97 cm

B. 8.97 cm

C. -10.97 cm

D. 10.97 cm

34. An upright image is magnified, appearing to be four times the size of the object's when the object is placed 26.9 cm from the lens. Determine the focal length of the lens.

A. 15.9 cm

B. 25.9 cm

C. 35.9 cm

D. 45.9 cm

35. Matthew's new Bug Habitat toy comes with a built in magnifier, allowing Matthew to get a close-up view of his captive ants, crickets, slugs, and other creatures. The magnifier has a focal length of 22 cm. Determine the distance which an ant must be located from the lens in order for it to appear magnified by a factor of 12.

A. 10 cm

B. 20 cm

C. 30 cm

D. 40 cm

36. A lens produces an inverted image which is one-fifth the size of the object. The lens has a focal length of 22.8 cm. Determine the object distance resulting in this magnification.

A. 127 cm
B. 137 cm
C. 147 cm
D. 157 cm

37. An object 7.0 cm high is placed 15 cm from a convex spherical mirror of radius 45 cm. Describe its image.

A. virtual, erect, 9.0 cm behind mirror, 4.2 cm high

B. virtual, erect, 45.0 cm behind mirror, 4.2 cm high

C. virtual, erect, 9.0 cm behind mirror, 0.6 cm high

D. virtual, inverted, 9.0 cm behind mirror, 4.2 cm high

38. What is the focal length of a convex spherical mirror which produces an image one-sixth the size of an object located 12 cm from the mirror?

A. 1.7 cm
B. -2.4 cm
C. 10.3 cm
D. 4.0 cm

39. A beam of light strikes the surface of water at an incidence angle of 60°. Determine the directions of the reflected and refracted rays. For water, n=1.33.

A. (a) 30° reflected into air, (b) 22° refracted into water
B. (a) 60° reflected into air, (b) 41° refracted into water
C. (a) 90° reflected into air, (b) 60° refracted into water
D. (a) 41° reflected into air, (b) 30° refracted into water

40. A luminous object and a screen are 12.5 m apart. What are the position and focal length of the lens which will throw upon the screen an image of the object magnified 24 times?

A. (a) 0.50 m from object, (b) +0.48 m
B. (a) 0.54 m from object, (b) +0.52 m
C. (a) 12.5 m from object, (b) 12.5 m
D. (a) 0.54 m from object, (b) +2.1 m

41. An image formed by a convex mirror is always _____.

A. virtual, upright and diminished
B. virtual, real and magnified
C. real, inverted and diminished
D. real, upright and magnified

42. Dentists use a _____ to focus light on the tooth of a patient.

A. concave mirror
B. convex mirror
C. plane mirror
D. cylindrical mirror

43. The focal length of a concave mirror is 15 cm. What is its radius of curvature?

A. 15 cm
B. 30 cm
C. 7.5 cm
D. 45 cm

44. The image produced by a magnifying glass is:

A. real, inverted and enlarged
B. virtual, inverted and enlarged
C. real, upright and enlarged
D. virtual, upright and enlarged

45. What principle is responsible for light spreading as it passes through a narrow slit?

A. refraction
B. polarization
C. diffraction
D. interference

46. What principle is responsible for alternating light and dark bands when light passes through two or more narrow slits?

A. refraction
B. polarization
C. diffraction
D. interference

47. What principle is responsible for the fact that certain sunglasses can reduce glare from reflected surfaces?

A. refraction
B. polarization
C. diffraction
D. total internal reflection

48. The principle which allows a rainbow to form is

A. refraction
B. polarization
C. dispersion
D. total internal reflection

49. When a light wave enters into a medium of different optical density,

A. its speed and frequency change
B. its speed and wavelength change
C. its frequency and wavelength change
D. its speed, frequency, and wavelength change

50. Light of wavelength 575 nm falls on a double-slit and the third order bright fringe is seen at an angle of 6.5^0. What is the separation between the double slits?

A. 5.0 µm
B. 10 µm
C. 15 µm
D. 20 µm

51. Two light sources are said to be coherent if they

A. are of the same frequency
B. are of the same frequency, and maintain a constant phase difference
C. are of the same amplitude, and maintain a constant phase difference
D. are of the same frequency and amplitude

52. A triangular glass prism with an apex angle of 60^o has an index of refraction n=1.5. What is the smallest angle of incidence for which a light ray can emerge from the other side?

A. 17.9^0
B. 27.9^0
C. 37.9^0
D. 47.9^0

53. You illuminate two slits 0.50 mm apart with light of wavelength 555 nm and observe interference fringes on a screen 6.0 m away. What is the spacing between the fringes on the screen?

A. 5.7 mm
B. 6.7 mm
C. 7.7 mm

D. 8.7 mm

54. For a given grating, it is observed that a third-order line *(m = 3)* of wavelength 465.3 nm overlaps a second-order line (has the same Θ as a line with *m = 2*). The wavelength of the second-order line is:

A. 498 nm
B. 598 nm
C. 698 nm
D. 798 nm

55. A diffraction grating has 12600 rulings uniformly spaced over 25.4 mm. It is illuminated at normal incidence by yellow light from a sodium vapour lamp. This light contains two closely spaced lines (the well-known sodium doublet) of wavelengths 589 nm and 589.59 nm. At what angle will the first order maximum occur for the first of these wavelengths?

A. 17^0
B. 27^0
C. 37^0
D. 47^0

56. The hydrogen spectrum has a red line at 656 nm and a violet line at 434 nm. What is the angular separation between these two spectral lines obtained with a diffraction grating that has 4500 lines/cm in the first order?

A. 4.91^0
B. 5.91^0
C. 6.91^0
D. 7.91^0

57. An echellette grating containing 1450 blazes (lines) per millimetre was irradiated with a polychromatic beam at an incident angle of 48^0 to the grating normal. Calculate the wavelengths of radiation that would appear at an angle of reflection of 20^0 for the first order.

A. 449nm
B. 549nm
C. 649nm

D. 749nm

[57 x 2 = 114]

SECTION B

QUESTION 1

1.1 Differentiate between heat and temperature. (2)

1.2 A piece of metal with a mass of 1.1 kg, specific heat of 200 J kg^{-1} $°C^{-1}$, and initial temperature of 100 ^{0}C is dropped into an insulated jar that contains liquid with a mass of 3.7 kg, specific heat of 1000 J kg^{-1} $°C^{-1}$, and initial temperature of 0 ^{0}C. The piece of the metal is removed after 7 seconds, at which time its temperature is 20 ^{0}C. Determine the temperature of the liquid after the metal is removed. Neglect any effects of heat transfer to the air or to the insulated jar.
(4)

1.3 A piece of metal with a mass of 1.1 kg, specific heat of 200 J kg^{-1} $°C^{-1}$, and initial temperature of 100 ^{0}C is dropped into an insulated jar that contains liquid with a mass of 3.7 kg, specific heat of 1000 J kg^{-1} $°C^{-1}$, and initial temperature of 0 ^{0}C. The piece of the metal is removed after 7 seconds, at which time its temperature is 20 ^{0}C. Determine the average rate at which heat is transferred while the piece is in the liquid. Neglect any effects of heat transfer to the air or to the insulated jar.
(4)

1.4 A combination of 0.233 kg of water at 22.2 ^{0}C, 0.234 kg of aluminium at 68.8 ^{0}C, and 0.245 kg of copper at 73.3 ^{0}C is mixed in an insulated container and allowed to come to thermal equilibrium. Determine the final temperature of the mixture. Neglect any energy transfer to or from the surroundings and assume the specific heat of copper is 387 J kg^{-1} $°C^{-1}$, the specific heat of aluminium is 900 J kg^{-1} $°C^{-1}$ and the specific heat of water is 4186 J kg^{-1} $°C^{-1}$.
(4)

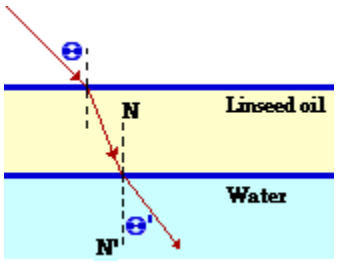
[14]

QUESTION 2

2.1 State Snell's law. (1)

2.2 State the conditions for total internal reflection to occur. (2)

2.3 The diagram at the right shows a ray of light travelling through air towards a thin layer of linseed oil (n = 1.50) resting on top of water (n=1.33). The light ray approaches the linseed oil at an angle of incidence of 48.2°.



2.3.1 Determine the angle of refraction at the air-linseed oil boundary.(3)

2.3.2 Determine the angle of refraction at the linseed oil-water boundary. (3)

2.4 The index of refraction for violet light in silica flint glass is 1.66, and that for red light is 1.62. What is the angular dispersion of visible light passing through a prism of apex angle 60^o if the angle of incidence is 50^o?
(4)

13]

QUESTION 3

3.1 Hydrogen emits violet light with a wavelength of 410 nm and red light with a wavelength of 656 nm. A parallel beam of hydrogen light is normally

incident on a diffraction grating that has 5500 lines per cm. What is the angle between the second order red line and the third order violet line that appear close together?

(4)

3.2 Monochromatic light from a He-Ne laser (632.8 nm) is incident on a diffraction grating containing 5000 lines/cm. Determine the angle of the first-order maximum.

(3)

3.3 Light of wavelength 580 nm is incident on a slit of width 0.300 mm. An observing screen is placed 2.00m from the slit. Determine the position of the first order dark fringe from the centre of the screen. (2)

[9]

FORMULA SHEET

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$m = \frac{-d_i}{d_o} = \frac{h_i}{h_o}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1\lambda_1 = n_2\lambda_2$$

$$n = \frac{c}{v}$$

$$c = f\lambda$$

$$c = 3 \text{ x } 10^8 \text{ m/s}$$

$$d \sin\theta = m\lambda$$

$$d = \frac{1}{N}$$

$$w = \frac{2\lambda L}{d}$$

$$\Delta x = \frac{D\lambda}{d}$$

$$\sin i_1 = n \sin r_1$$

$$\sin i_2 = n \sin r_2$$

$$D = (i_1 - r_1) + (i_2 - r_2)$$

$$n = \frac{\sin[\frac{D_m + A]}{2}}{\sin[\frac{A}{2}]}$$

$$Q = mc\Delta t$$

$$Q = mL$$

$$P = \frac{W}{t}$$

$$\Delta l = \alpha\, l\, \Delta T$$

$$\Delta A = 2\alpha\, A\, \Delta T$$

$$\Delta V = 3\alpha\, V\, \Delta T$$